Response to Reviewers

February 10, 2017

We thank the referee for the valuable recommendations, that gave us the opportunity to make more clear our paper and to clarify some feature of our simulation effort. In the following we are going to answer point by point to the open issues that the referee raised.

Q1: The simulation is in both cases, mRICH and dRICH, based on GEMC. I am wondering if the same basic parameters, e.g. wavelength limits, QE, aerogel properties, etc, were used? If so, this should be stated at the beginning so that these topics do not have to repeated in each section again. Indeed, it is not clear for the mRICH which parameters were used!

Concerning the aerogel, the optical parameters have been inferred from the detailed study done by the CLAS RICH collaboration and adapted to the specific case: mRICH or dRICH. This statement have been placed in the introductory paragraph. For the rest the simulations and the basic parameters are almost independent.
For the mRICH first prototype simulation parameters are:

- Aerogel
  - 3.3cm thick
  - n=1.03
- Fresnel lens
  - 100 grooves per inch (caption of figure 1)
  - 3"=7.62cm Focal length
- Photon sensor
  - Hamamatsu H8500
  - Spectral response 300-650nm
  - Q.E. peak at 400nm, 30%

The main parameters have been added in the mRICH paragraph.

Q2: Using a Fresnel lens is certainly a novel idea. However, Fresnel lenses are usually not used for imaging applications due to the fact that they break up the wavefront. In addition, the image quality is further degraded for off-axial light rays which is the case for a Cherenkov detector. Therefore, it *would be important to learn, how much the momentum coverage is improved by using such a lens. Especially, since the lower image in Fig. 1 suggests a lot of scattered photons due to the sharp edges of the Fresnel lens.*

Advantage of Fresnel lens is its slim geometry which lowers particle interaction inside lens, as well as decreases the volume of the detector. However, Fresnel lens is not the only candidate of lens options. We are still exploring other possibility.
Shown in figure 1 and 2 (see below) are uncertainty of single photon measurement and separation power (number of sigma), respectively. Figure 1 and 2 are from simulation result with different mRICH detector setup, and with infinitely small pixel size. Figure 1 shows that lens-based design decreases uncertainty of single photon measurement by approximately a factor of 5 if a 3 focal length Fresnel lens is used while detector dimension unchanged. Figure 2 shows that detector PID performance may reach 3-sigma up to 8GeV/c and above 10 GeV/c if 3 and 6 focal length Fresnel lenses are used respectively.

Q3: What are the dimensions for the mRICH? There are no numbers given anywhere in the text!

Excluding readout electronics, the first prototype is 11.5cm x 11.3cm x 11.3cm.

Q4: Figure 3 is not suited to show that the detector is made of six sectors! Either drop this line or change Fig. 3.

The line has been dropped, furthermore Fig. 3 has been changed to clarify the dRICH arrangement. We plan to arrange the detector in six sectors, but this feature is not so relevant in the current paper.

Q5: For the dRICH, the individual contributions to the single photon Cherenkov angle resolution are shown in Fig. 4. It is not clear to me, why the emission contribution for the gas radiator shows a minimum at 10 degrees. Could you please comment on this feature?

In a mirror focused RICH the emission uncertainty is exactly zero only if the photons are collected on the focal surface.
For a spherical mirror the focal surface is approximately a sphere with radius one half the radius of the mirror. But this is not exactly true because of the spherical aberrations: in a 2D case one has

$$f = R\left(1 - \frac{1}{2cos\theta}\right) \tag{1}$$

where θ is the angle of incidence of a ray respect to the normal to the mirror surface, f is the focal length and R the radius of the mirror. The condition $f \simeq R/2$ is valid only for small θ.
Therefore, in the case of a spherical mirror focused RICH, the focal surface depends on the polar angle of the emitting track. In the case of dRICH, given the relatively small space at disposal to arrange the photo-sensor surface, we have a sizable tilt angle for the optical axis of the mirrors with a relatively small optical path. The optical focal surface is quite spread around a naive sphere of radius $R/2$. In the presented simulation the detector surface is a sphere of radius about $0.65 \cdot R$ placed to minimize the emission uncertainty for central angles. In the future, we plan to study a

ladder-like geometry for the photo-sensor plane in order to fit as much as possible the real focal surface.
Few words (given the three pages at disposal) have been added in the paper (in the caption of Fig. 4) to mention this feature.

line 73: "avoiding chemical degradation of the aerogel" in addition it would be nice to put a reference to the LHCb publications on this topic here;

We know that in LHCb the aerogel radiator has been found to be of reduced effectiveness at high luminosity and will be removed, as explained in the LHCb Particle Identification Upgrade Technical Design Report. We did not find specific references on this topic. If the referee could suggest some specific reference we will be happy to add it. On the other hand the HERMES collaboration applied an acrylic shield in front of the aerogel and it worked. It should be pointed out that the occupancy for HERMES was about one track per event, instead of the larger occupancy of LHCb. The EIC occupancy will be close to one track per event.

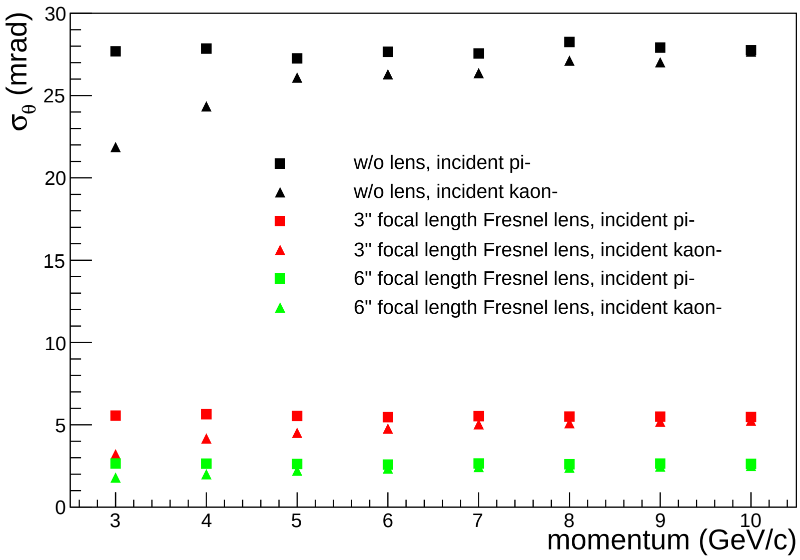
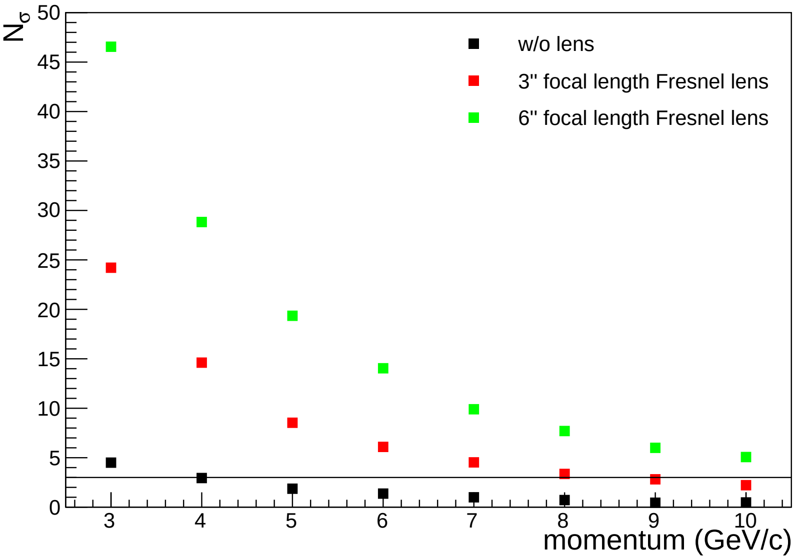


Figure 1:



N_σ
50
45
40
35
30
25
20
15
10
5
0
w/o lens
3" focal length Fresnel lens
6" focal length Fresnel lens
3
4
5
6
7
8
9
10
momentum (GeV/c)

Figure 2: